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Extreme Climatic Upheaval, Emergency Resource Adaptation, and the Emergence of Folkloric Belief: Geomythic Origin of Sea Serpents from Animals Becoming Entangled in Fishing Gear During New England's Nineteenth-Century Social-Ecological Crisis

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Abstract
In 1815, the eruption of the Indonesian volcano, Tambora, produced a social-ecological crisis experienced around the world. In New England, the relationship of humans to their coastal ecosystem was completely transfigured. Slaughter of livestock for want of fodder and the collapse of the anadromous fishery due to spawning failures necessitated turning to mackerel. The result of this regional resource shift was the sudden and massive deployment of fishing gear in coastal waters. Coincident to these events, what would become the world's most sighted 'sea serpent' became prominent around Gloucester, Massachusetts. Careful parsing of eyewitness descriptions of physical and behavioral characteristics provided to the region's natural history society strongly suggests that this is an early documented case of a marine animal entangled in fishing gear. This supports other work positing such entanglement as being behind many sea monster sightings.

Keywords Tambora volcanic eruption · Extreme climatic cooling · Fisheries resource adaptation · Entanglement · Sea serpent · New England

Introduction

In an article based upon his book, *Tambora: The Eruption that Changed the World*, Wood (2016) recounts the ensuing origin of Mary Shelley's Creature from the "Frankenstein weather" of 1816, the monster a metaphor for the physically ravaged hordes of wandering climatic refugees during Europe's last major subsistence crisis. Here, I advance a new theory to explain how that same volcanic eruption also gave birth to a *real* creature construed to be a 'monster' whose legacy is as lasting and influential as Shelley's. Commenting upon the influence of the Tambora eruption with regard to nineteenth-century Letters, and the lessons arising therefrom for the Anthropocene, Higgins (2016) wrote: "The most interesting Romantic literature is not so much concerned with what we 'do' to nature or vice versa, but with the *entanglement* of human and nonhuman agents" (my italics), which perfectly captures the thesis of my forensic interpretation of this particular piece of social-ecological history.

Because folkloric beliefs often have a scientific basis (Masse *et al.* 2007), massive events such as floods, tsunamis, earthquakes, and volcanic eruptions can have profound and lasting influences on human memory. The nascent discipline of geomythology explores the links between geologic events and the origin of myths and legends. Although Vitaliano (2007) dismissed the idea that phenomena such as the Loch Ness monster could ever have "convincing geomythological explanations," other work has shown that monsters can indeed be created out of fossils, folklore, and fervent imagination (e.g., Mayor 2000; McGowan-Hartmann 2013). In this paper I posit how history's most significant volcanic eruption led to history's most sighted and studied 'sea serpent.'

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The Unidentified Marine Object Construed as a 'Sea Serpent'

There have been hundreds of sea serpent sightings from every part of the globe during the last four centuries (Oudemans

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1892; Heuvelmans 1968). Most sightings are either of an extremely brief duration or made by a single observer, and thus often easy to dismiss. This is not the case, however, with respect to the so-called 'Gloucester Sea Serpent' reported off the New England coast during the early nineteenth century. This particular unidentified marine object (UMO) is unique in the corpus of maritime mysteries. Seen by hundreds, if not thousands, of people from all walks of life, often for durations of many minutes, and in some cases, even hours, it remains the most sighted sea serpent in history. It is therefore impossible to simply dismiss these sightings as being mass hysteria of the sort that gripped a very limited number of schoolgirls and nuns reporting, respectively, witches in Salem or devils in Loudun. Clearly the people in New England at this time did see *something* in the water, which appeared to them to be different from the norm, their confirmation bias kicking in to suggest it to have been a sea serpent. The sightings of the Gloucester Sea Serpent have been described in narrative form in popular books (O'Neill 1999; Soini 2010). First-person accounts and legally sworn testimonies in their own words are provided for selected (Oudemans 1892; Heuvelmans 1968), and for the entire corpus (France 2019), of eyewitnesses.

The result of all these sightings was that, more than a century before "Nessie," the "sea serpent phenomenon" (sensu Burns 2014) of New England captured worldwide attention. The mysterious UMO gave birth to what might be called the region's first ecotourism industry, with hotels constructed and sea serpent cruises conducted. All this attention led to hundreds of news articles in regional broadsheets, as well as numerous works of fiction, including dramatic productions, about the mysterious monster (Burns 2014; France 2019).

The Gloucester Sea Serpent is the most thoroughly investigated sea serpent of all time. The detailed interviews of eyewitnesses conducted by qualified observers and legal authorities under the auspices of the region's learned natural history society soon after the bulk of the sightings (e.g., Davis *et al.* 1817), lend an authenticity to these accounts that is absent in many other similar contemporaneous anecdotes. Paxton (2009), in his analysis of potential biases in eyewitness observations of sea serpents, actually excluded data from the Gloucester case as being *too* accurate in comparison to the other anecdotal sightings he examined. Indeed, applying Champagne's (2001) objective evaluation of the credibility of UMO sightings revealed that the subset for the Gloucester UMO had a statistically significantly higher rating than those for all other UMO sightings (France 2019).

At a time when the world's leading naturalists considered the study of sea monsters to be not only a legitimate but also a meritorious field of scholarship (e.g., Regal 2012), dozens of articles were published in the world's leading journals (Lyons 2009). Many of these papers made specific reference to the UMO of Gloucester (Brown 1990; Burns 2014; France 2019). Sea serpents are therefore an essential part of both maritime and scientific historical inquiry.[1]

The Gloucester Sea Serpent is regarded among cryptozoologists as "the best-documented evidence that sea-serpents exist" (Bauer 2013). In consequence, cryptozoology traditionally uses the Gloucester sightings as the touchstone of authority and credence to claims made about other aquatic cryptids for which less convincing 'data' are available (e.g., Gould 1934).

The Eruption's Influence on Global Climate with Ensuing Social-Ecological Repercussions and Resource Adaptations in New England

The April 1815 eruption of the Indonesian volcano Tambora ejected 100 km^2 of ash, acid aerosol, and water vapor into the stratosphere, which produced repercussions felt around the world (e.g., Wood 2014). Global temperatures dropped by 1° to 1.5 ° C, with extreme weather events experienced in northern latitudes leading to 1816 being referred to as "the year without a summer" (Stommel and Stommel 1983). Evidence from polar ice cores (Fig. 1) indicates a sudden extreme climate event also took place in 1809 due to another volcanic eruption of global significance (Guevera-Murua *et al.* 2014), so that the 1810–19 decade remains the coldest in the historical record (Cole-Dai *et al.* 2009).

Northeastern North America appears to be a region whose climate is especially sensitive to volcanic forcing, such as occurred due to these eruptions (Gennaretti *et al.* 2014). Massachusetts experienced abnormally low daily temperatures (van der Schrier and Jones 2008) in the years both after as well as before the eruption of Tambora (Fig. 2). The spring of 1816 was the coldest in two centuries, with large sections of the Maine coast remaining icebound. Things did not improve much throughout the summer, with snowfall and killing frosts occurring each month, leading locals to refer to 1816 as "Eighteen-Hundred-and-Froze-to-Death" (Wood 2014). The 1816 New England growing season was the shortest ever recorded, 60 to 70 days, compared to normal durations of about 120 days.

Manifold repercussions of climatic cascades can permeate through marine food webs (e.g., Hough-Guldberg and Bruno 2010). The marine littoral is a social-ecological system characterized by complex interrelations among humans and natural resources (e.g., Pollnac *et al.* 2010). In consequence, the extreme weather generated from the eruption of Tambora not long after another eruption in 1809 triggered a precise sequence of changes evident in the historical record that had a marked

[1] Bolster (2012) entitled one of the six chapters in his environmental history of the fishing industry in the North Atlantic, 'The Sea Serpent and the Mackerel Jig,' and noted that: "No marine environmental historian worth his or her salt can afford to ignore early nineteenth-century sea serpents."

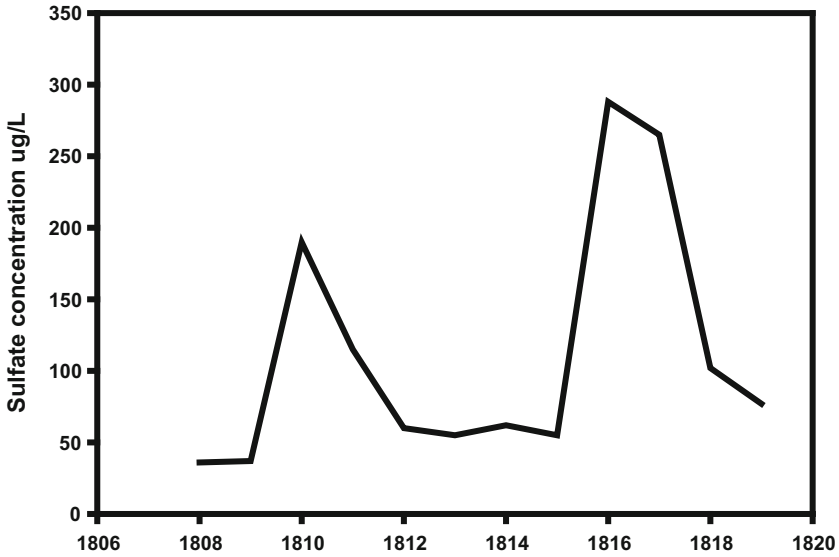

Fig. 1 Average sulfate deposition from two ice cores taken at the South Pole Antarctica and the central summit of Greenland. Derived from graphed data in Cole-Dai *et al.* (2009). The global stratospheric impact of the 1815 Tambora and another 1809 volcanic eruption are clearly discerned

impact on the ecosystem and humans in the Gulf of Maine. These climatic changes affected a maritime population already reeling and recovering from the geopolitical effects of Thomas Jefferson's Embargo Act of 1808–1809, the War of 1812–1814, and the Royal Naval Blockade of New England 1812–1815, all of which severely disrupted fisheries (Bolster 2012).

An unprecedented environmental and social crisis ensued in the years 1816 and 1817 (Wood 2014). Crop failures in the summer-less year were so severe that livestock were slaughtered for want of fodder to keep them alive through the subsequent winter, producing a situation in 1817 wherein soup kitchens became established in urban centers and large numbers of rural people were forced to emigrate to avoid famine (Alexander *et al.* 2017). By 1817, therefore, little protein was left in the region other than the seasonal arrival of spawning fish followed by their offshore predators. In consequence, New Englanders turned to the sea as never before for a reliable source of food. The problem, however, was that the spawning runs of anadromous fishes such as alewife (*Alosa pseudoharengus*) and shad (*Alosa sapidissima*) faltered in 1816 due to the fish being met with inhospitable temperatures in many ponds and streams still ice-covered late into the spring. A regional drought in 1817 may have acerbated the problem through impeding inland fish passage in developed rivers (i.e., those with dams) due to low base flows (Alexander *et al.* 2017). The result was the collapse of the anadromous fishery (Fig. 3). In contrast, offshore spawning species such as mackerel (*Scomber scombrus*), herring (*Clupea harengus*), and menhaden (*Brevoortia tyrannus*) could avoid the frigid freshets and were not as adversely affected. Consequently, people turned to mackerel, the most abundant species close to commercial distribution centers for food, fodder, and revenue-generating exports. This led to the invention by a Gloucester fisherman of the mackerel jig (Bolster 2012). The simple act of adding a bit of shiny metal to the barb to increase its attractiveness completely revolutionized the offshore fishery, and was in wide use by 1820. The regional resource switch from riverine to coastal fishes by New England fishermen following the Tambora eruption (Fig. 4) is a clarion example of what Holland (2012) refers to as complex adaptive systems theory. As Alexander *et al.* (2017) state: "Two hundred years ago, societal responses to a natural disaster, born of necessity, shifted cultural memory and expectations, transforming coastal communities, humans and aquatic, from one dynamic social and ecological regime into another."

The Volcano's Real Monstrous Offspring

Johnson (2005) describes the current threat posed to animals by fishing gear: "By some estimates, there are currently over a million crab and lobster pots dotting the surface of the sea off New England alone. Early European settlers used to joke that one could walk across the water of the Northwest Atlantic on the backs of the cod. Now they make the same joke about the lobster pot buoys, and the Northwest Atlantic, including the offshore banks, has become an obstacle course for feeding whales."

In early nineteenth-century New England, mackerel and herring were caught through towed arrays of hooks, handheld jigging, small pulled seines, and gill-nets or 'meshes' (Bolster 2012). Beginning in 1816, the entire coast became covered by a network of lines and deployed nets as people attempted to stave off starvation. Nearshore netting was used for mackerel as well as herring and menhaden, the latter as baitfish for jigging. Migrating animals unaccustomed to and therefore unwary of fishing nets were suddenly faced with a labyrinth of fishing gear to navigate. On the other hand, here

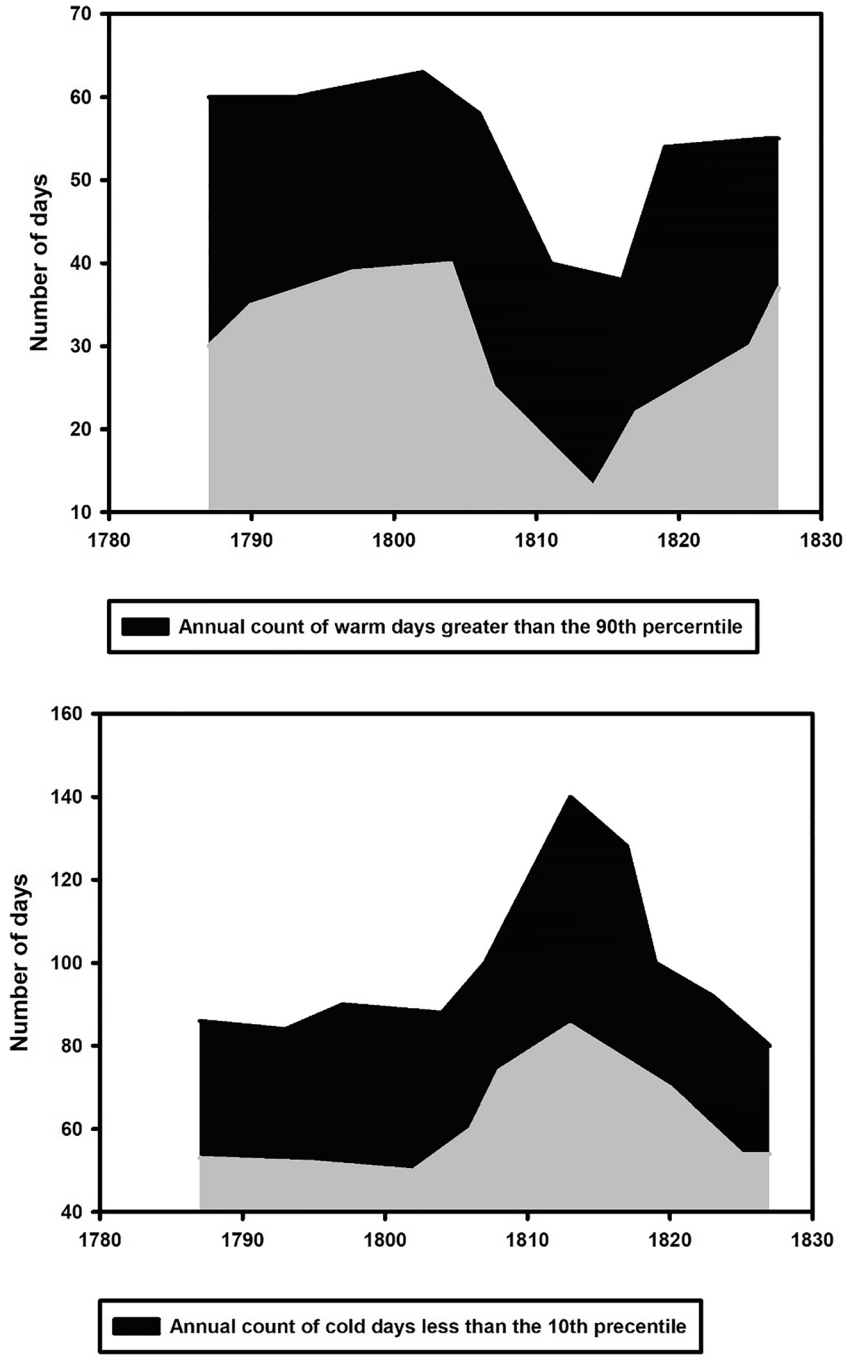

Fig. 2 Extreme weather events in Salem, Massachusetts caused by the volcanic eruptions of 1809 and 1815. Derived from graphed data in van der Schrier and Jones (2008) (whom did not make the volcanic association). Upper panel shows the annual counts of warm days greater than the 90th percentile, and lower panel shows the annual counts of cold days less than the 10th percentile (solid black areas indicates daily ranges in both cases)

prominently and conveniently collected in one place was a huge mass of their prey. A somewhat similar situation developed in the summer of 2017 when North Atlantic right whales (*Eubalaena glacialis*), of which only about 500 are known to exist, switched their summer feeding grounds from the quiet and relatively unfished waters of the Bay of Fundy, to those of the Gulf of St. Lawrence, which is riddled with fishing traps and ropes and filled with commercial boat traffic. The result was that more than a dozen whales were killed by entanglement and boat collisions, fully 3% of the entire species.

Perhaps, therefore, it is no coincidence that post-Tambora the frequency of sea serpent sightings suddenly increased dramatically in New England (Fig. 4). O'Neill (1999) reports that the rate of sea serpent sightings for the 8 years preceding the "mackerel year" of 1816 (Alexander *et al.* 2017) was 1.3 pa compared to 11.3 pa for the following 8 years. I believe that the climatic and consequent sociological disruption caused by this historic volcanic eruption resulted in the appearance of history's most sighted sea serpent in 1817. The Gloucester Sea Serpent and expansion of the mackerel fishery

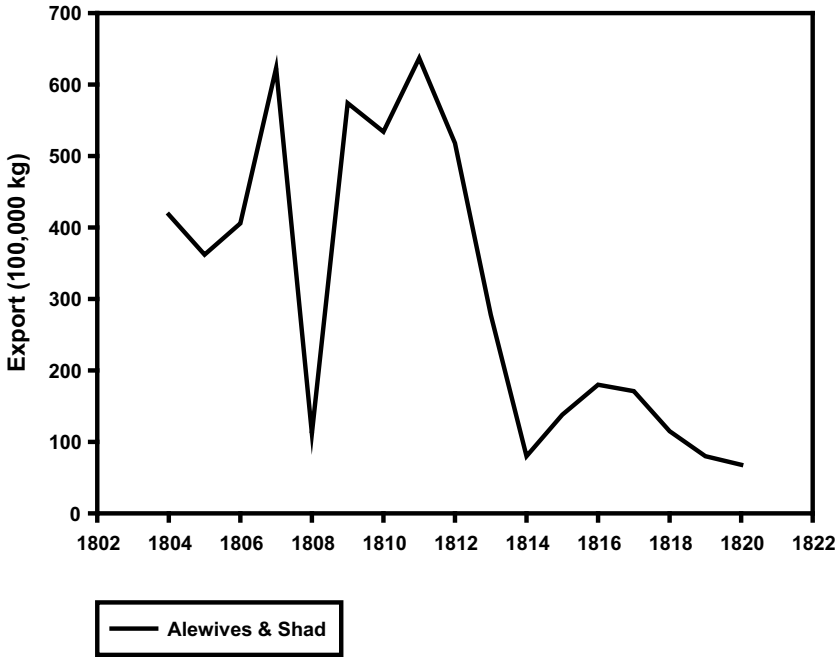

Fig. 3 Combined yearly amounts of anadromous fish (alewives and shad) exported from watersheds north of Cape Ann and from Cape Ann to Cape Cod. Derived from fish inspectors' data in Alexander *et al.*'s (2017) supplementary tables. The important point to note is that following cessation of President Jefferson's Trade Embargo Act of 1808, the fishery yield immediately and completely recovered, notwithstanding the 1809 Unknown eruption. This was very different from the subsequent depression of the fishery due to the outbreak of war of 1812 – 1814, wherein the extreme weather caused by the eruption of Tambora in 1815 prevented a similar recovery

are closely linked events (Figs. 4 and 5), as Bolster (2012) also recognized.

Through historical, textural reinterpretation, based on a thorough examination of all 90 eyewitness testimonies, the evidence is compelling that the Gloucester Sea Serpent was indeed an entangled animal, albeit probably not a cetacean (France 2019). The elongated 'body' of the UMO was obviously inanimate, given that it was oblivious to being approached and hit by numerous boats, as well as being completely impervious to being struck by musket fire, harpoons, and even canon shot (Table 1). The body was occasionally seen draped upon the shore, but most often observed floating on the surface, sometimes immobile for many minutes and at other times displaying a speed of locomotion that was biomechanically impossible through the undulations of the numerous articulated body segments or 'bunches,' thought to resemble barrels, casks, or buoys, of which it was comprised (Table 2). And finally, there is the so-called 'duck test' of abductive reasoning, wherein an object by logical inference actually *is* what is described, in this case, a long array of buoys or kegs tied together as if part of a herring net (Table 3).

There is really only a single logical (i.e., non-cryptozoological) explanation that can adequately fit all the characteristics described in the sightings of the Gloucester UMO (France 2019): an animal non-lethally entangled in maritime debris. In this regard, just as the Tambora volcanic eruption and ensuing extreme "Frankenstein weather" gave birth to fiction's most famous living-dead monster, so too did the starvation-motivated rapid resource shift to coastal fishing with the consequent deployment of thousands of fishing nets spawn a real living-dead sea monster. "Living-dead," because though entanglement can be non-lethal, occurring over several years for some marine animals (e.g., Neilson *et al.* 2009), it is ultimately debilitating, and will almost certainly bring about premature mortality through impeded swimming and/or infected wounds (Derraik 2002). So just as Shelley's ambling monster can be regarded as a walking-dead metaphor for suffering climatic refugees (Wood 2014, 2016), the Gloucester sea monster can be thought of as a swimming-dead symbol for climatic-stressed food webs, both providing allegorical representations for the Anthropocene (Higgins 2016).

The Eruption's Legacy on Marine Resource Use and Propagation of Entangled 'Sea Serpents' in New England

Wood (2014) states: "Nor should we view Tambora's global impact 'merely' as an extreme weather regime limited to the late 1810s …The social changes wrought by climatic upheaval on the scale of 1815-18 may be traced decades into the future."

From the "mackerel year" of 1816, onwards, there was a hysteresis change in New England's coastal fishery as it expanded from small, shore-hauled nets and weir-traps straddling streams and rivers to larger nets that could be deployed in coastal bays and offshore waters, aided by the shift to purse seining in the 1880s. Henceforth, mackerel and other pelagic fishes became both a lucrative commercial product as well as a utilitarian source of food, as once alewife and shad had been. The influence of the Tambora eruption on New England society through the contingent alterations to its fishery therefore

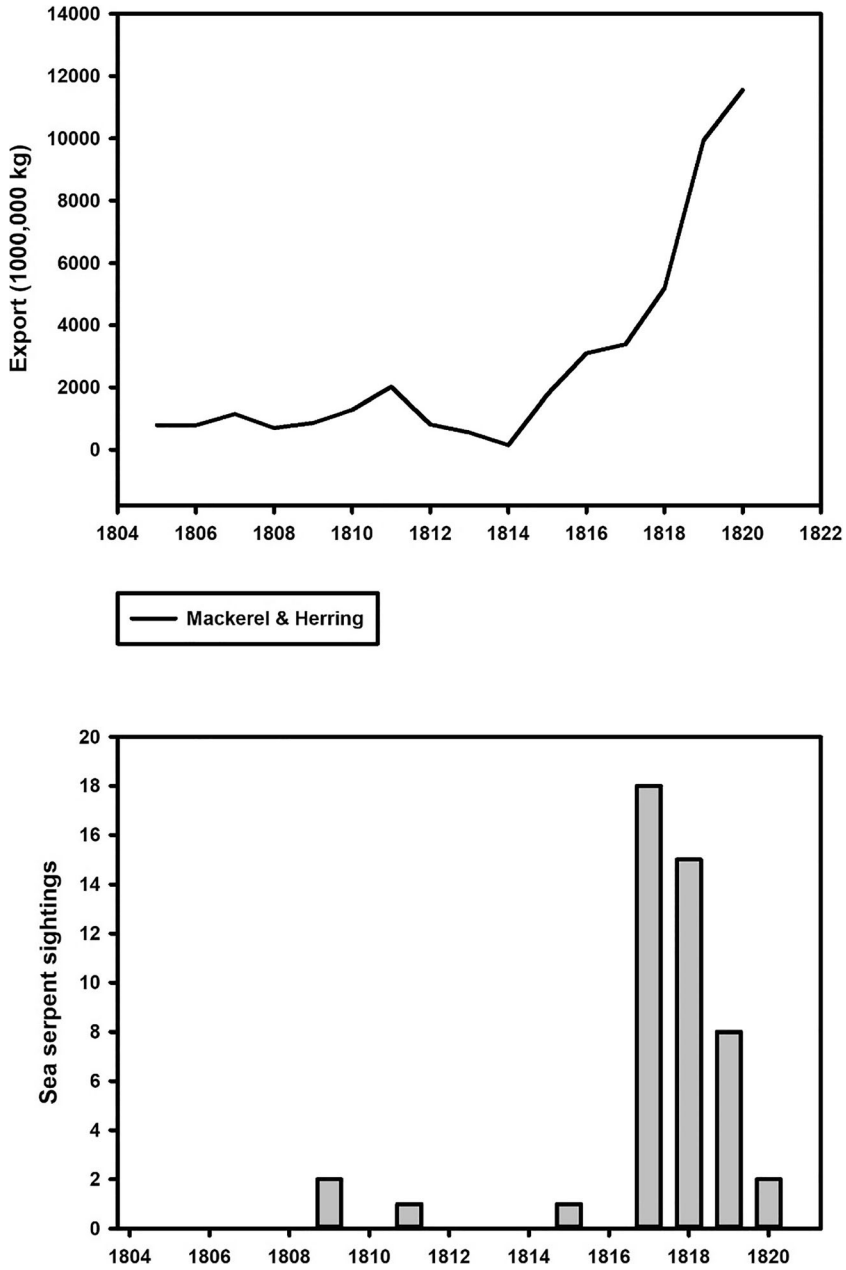

Fig. 4 Parallel expansion of the fishery on pelagic species following the climatic disruption caused by Tambora on anadromous species and the increased incidence of purported sea serpents sightings in New England. Upper panel - combined yearly amounts of pelagic fish (mackerel and herring) exported from the Gulf of Maine. Derived from fish inspectors' data in Alexander *et al.*'s (2007) supplementary tables. Lower panel – annual sightings of sea serpents in New England. These data from O'Neill (1999)

"created a new range of adaptive opportunities that were transformative" and permanent (Alexander *et al.* 2017).

Entanglement is widely believed to be a modern phenomenon related to the advent and widespread use of non-degradable plastic in the middle of the twentieth century (NOAA 2014), due to the assumption that materials made from hemp and other natural fibers will "lose their resilience in usage and if lost or discarded at sea [will] tend to disintegrate quickly" (Gregory 2009). Consequently, it was only in the mid-1980s that scientists came to recognize the severity of the problem of marine debris and its implications for wildlife conservation. Indeed, a literature search revealed only a single publication on the subject prior to 1970 (Vegter *et al.* 2014).

Compared to modern ropes, which are almost exclusively made of nylon or polyethylene, earlier ropes made from natural fibers will have deteriorated more rapidly, but nevertheless would have lasted long enough to pose a threat to susceptible wildlife. Hemp actually becomes "stronger when wet and does not rot easily in water," owing to the hydroscopic nature of the fiber (McCaskill 2009). Furthermore, hemp ropes were often impregnated with dye or pine tar to slow down their rate of deterioration (Bekker-Nielsen and Casola 2010). The percentage tensile strength and longevity of wetted rope can increase up to 20% and extend beyond a year given proper treatment with preservatives (Aiken and Purser 1936), and in certain circumstances ropes made of manila hemp can have a

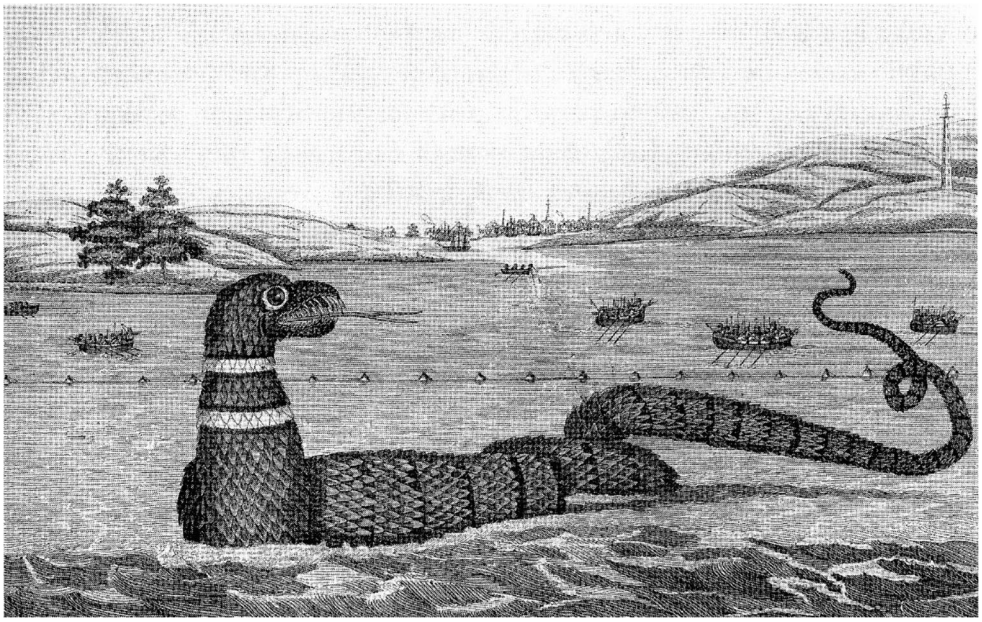

Fig. 5 The most famous and, despite its title ("Sea Serpent engraved from a drawing taken from life as appeared in Gloucester Harbour, August 23, 1817"), the most inaccurate, illustration of the Gloucester Sea Serpent. Widely republished, including as the cover for Soini's (2010) book, and being used for advertising and selling gift-shop items by the Cape Ann Museum during its bicentenary exhibition of the sightings in 2017, it remains the stuff of cryptozoological fantasy. Nevertheless, the illustration is important with respect to its depiction of the sea serpent sharing the harbor with a flotilla of small fishing vessels and, most significantly, a long string of floats from of fishing net, which at a distance resembles the dorsal ridges to which so many eyewitnesses gave sworn testimony were a characteristic feature of the UMO. Artistic representations that more accurately correspond to eyewitness descriptions of the many-humped sea serpent do exist (see Burns 2014 and France 2019)

durability equal to nylon or polyethylene (Kristjonsson 1971). Indeed, the rise in popularity of manila hemp during the nineteenth century was particularly due to its natural oils providing resistance to deterioration, thereby eliminating need for tarring to prevent rot (McCaskill 2009). In some cases, hemp ropes were even reinforced with braided wire (Goode *et al.* 1884).

Table 1 Descriptions of the Unidentified Marine Object (UMO), imagined as a sea serpent, observed between 1815 and 1824 in New England, and indicative of an inanimate object that is oblivious to the surroundings and impervious to assault

"The animal did not utter any sound, and did not appear to notice anything."
"We immediately rowed from him, and at first concluded to pass by his tail; but feared we might strike it with the boat, concluded to pass around his head, which we did, by altering our course. He remained in the same position, till we lost sight of him. We approached so near to him that I could have reached him with my oar."
"The serpent passed out under the stern of our boat…then he stood in towards us again, and crossed our bow."
"…two [musket] balls were thought to hit his head, but without effect."
"…he has never showed any indications of a disposition to chase or attack any moving object or living creature."
"…neither…did he appear frightened, or in any degree disturbed by their sudden and near approach."
"I fired it at the head of the monster; my crew and myself distinctly heard the [cannon] ball and bullets strike against the body, from which they rebounded, as if they had struck against a rock…he almost touched the vessel…he dived, but in a moment we saw him appear again, with his head on one side of the vessel, and his tail on the other, as if he was going to lift us up and upset us. However, we did not feel any shock."
"…several whalers got within a few yards, but their harpoon bounced off the animal."
"[The monster] received, with apparent unconcern, seven or eight salvos [of musket fire] and went on playing on the surface."
"…reported firing upon it, but the balls did not seem to penetrate."

It is my contention that any rope and net material sufficiently durable to be useful to fishermen or mariners will have posed a threat to entangle by-catch. It is possible that entanglement in the nineteenth century may have lasted at least for months, and possibly several years, certainly sufficient time for an unfortunate animal to have been seen and misidentified as a sea serpent. An animal pulling a string of buoys, which during the nineteenth century shifted from blown-glass balls to much larger cork floats and even casks, could easily be misidentified as the undulating motions of a supposed sea serpent (Fig. 6). Indeed, the many-humped or serpentine form of sea monster is the predominant category based on the corpus of global sightings (Paxton and Naish 2019), and is actually referred to as the "string-of-buoys" typology by Heuvelmans (1968).

Furthermore, although it may seem surprising that so many eyewitnesses were unable to identify trailing gear or debris in their sightings, it is possible to observe in online photographs of entangled marine animals today lengths of entwined rope and matted netting, some festooned with kelp or other seaweed, that certainly give the impression of solidity, making it easy to imagine how such a structure could generate the illusion of an elongated body or fluke-less tail. The literature is rife with nineteenth-century mariners and fishermen with

Table 2 Descriptions of the UMO, imagined as a sea serpent, observed between 1815 and 1824 in New England, and indicative of having a body composed of multiple segments, likened by some, to resembling barrels

"I saw perhaps thirty or forty of those protuberances or bunches, which were about the size of a barrel."
"…about the size of a halfbarrel, apparently having joints from his head to his tail…fifty distinct portions…appeared rough and scaly."
"…he appeared to me to have joints, about the size of a two-gallon keg…the bunches…appeared about six inches above the surface of the water."
"…he saw 60 or 80 black substances on the water."
"…his humps plainly to be distinguished."
"I saw bunches on his back about a foot in height, when he lay extended on the surface."
"…occasionally exhibiting parts of his body, which appeared like rings or bunches…he appeared jointed."
"It was not, to be sure, a continuity of body, as the form from head to tail (except as the apparent bunches appeared as he moved through the water) was seen only at three or four asunder [i.e. apart from each other]."
"…of the size of a barrel about the body, which he formed into parallel rings, which—when he is on top of the water—are so prominent."
"His back…appeared to be irregular, uneven, and deeply indented…ridges or humps on his back."
"…which at first view resembled a ship's buoy."
"We counted twenty bunches, and we supposed them on average about five feet apart…His body was of the size of a sixty or eight-gallon cask."
"…his back appeared to be composed of bunches or humps, apparently about as large as, or a little larger than a half barrel."
"I perceived at a short distance eight or ten regular bunches or protuberances, and at a short interval three or four more…his bunches appeared to be not altogether uniform in size."
"The apparent bunches on his back they consider as arising from the construction of his body."
"I counted fourteen bunches on his back, the first one, say ten or twelve feet from his head, and the others about seven feet apart. They decreased in size towards the tail…The protuberances were not from his motion, as they were the same whether in sloe or rapid movement."
"There were several protuberances on his back, the highest point of which appeared to be seven or eight inches above the level of the water."
"The circumference of the animal was about the size of a common barrel…the protuberances on his back were about six feet apart."

considerable experience observing all manner of sea-life being fooled by such accumulations of debris and organic matter. Cases exist of dories deployed to capture an imagined sea serpent, only to find out that it was a length of periphyton-covered netting affixed to something underwater bobbing about in the tidal current, thereby seeming to be swimming rapidly. Indeed, in one encounter it was not until the successfully captured 'sea serpent' was actually hauled on deck and closely examined that the mistaken identification was detected (France 2018). In an era when the most highly respected biologists believed in the existence of sea monsters (Lyons 2009; Regal 2012) it was commonplace to thus identify any UMO.

Table 3 Descriptions of the UMO, imagined as a sea serpent, observed between 1815 and 1824 in Gloucester Harbor and elsewhere, and clearly indicative of a marine animal entangled in fishing gear or other maritime debris

"…his appearance in this situation was like a string of buoys. I saw perhaps thirty or forty of those protuberances and bunches, which were about the size of a barrel."
"…looked like the buoys of a seine"
"…with a good glass [I saw what] seemed like gallon kegs tied together"
"His body when out of the water looks like the buoys of a net, or a row of kegs, or a row of large casks"
"…of the size of a barrel about the body, which…are so prominent, that they resembled buoys attached to each other"
"[The body] appears in joints like wooden buoys on a net rope almost as large as a barrel, that the musket balls appear to have no effect on it, that it appears like a string of gallon kegs."
"…as he moved he looked like a row of casks following in a right line"
"He appears to be full of joints and resembles a string of buoys on a net rope, as is set in the water to catch herring. Others describe him as like a string of water casks…Two [musket] balls were thought to hit his head, but without effect."
"…resembled the link of a chain."
"The first view I had of him appeared like a string of empty barrels tied together, rising over what little swell of the sea there was."
"The back was composed of bunches about the size of a flour barrel, which were apparently about three feet apart…and looked like a string of casks or barrels tied together."
"The body, which is formed into parallel rings, which—when he is on the top of the water—are so prominent, that they resembled buoys attached to each other."
"…and to seem jointed, or like a number of buoys or casks following each other in a line."
"…the curvature and bunches on his back. To some he appeared jointed, or like a string of kegs or buoys connected on a rope."
"…giving the appearance of a long moving string of corks."

Indeed, a careful parsing of the texts and examination of accompanying illustrations (Fig. 7) in accounts of what were thought to have been sea serpents - locked in mortal combat with whales, resembling sea turtles with incongruously long and serrated tails, or strange snake-chelonian or snake-cetacean hybrid creatures - suggest that entanglement did occur during the nineteenth century. In reference to this theory, Deedy (2017) quotes a spokesperson for the U.S. National Oceanic and Atmospheric Agency (NOAA) that "experts agree anything left in the ocean could present an entanglement hazard for marine life," and the director of the entanglement response team with the Center for Coastal Studies, agreeing that "no doubt there has been an entanglement problem for as long as humans have been setting rope-based gear—plastic or not."

Long after temperatures had returned to normal, the continued expansion of the coastal fishery (Goode *et al.* 1884; Hoy and Clark 1967; Bolster 2012) ensured that one legacy of Tambora were recurrent reports of purported sea serpents

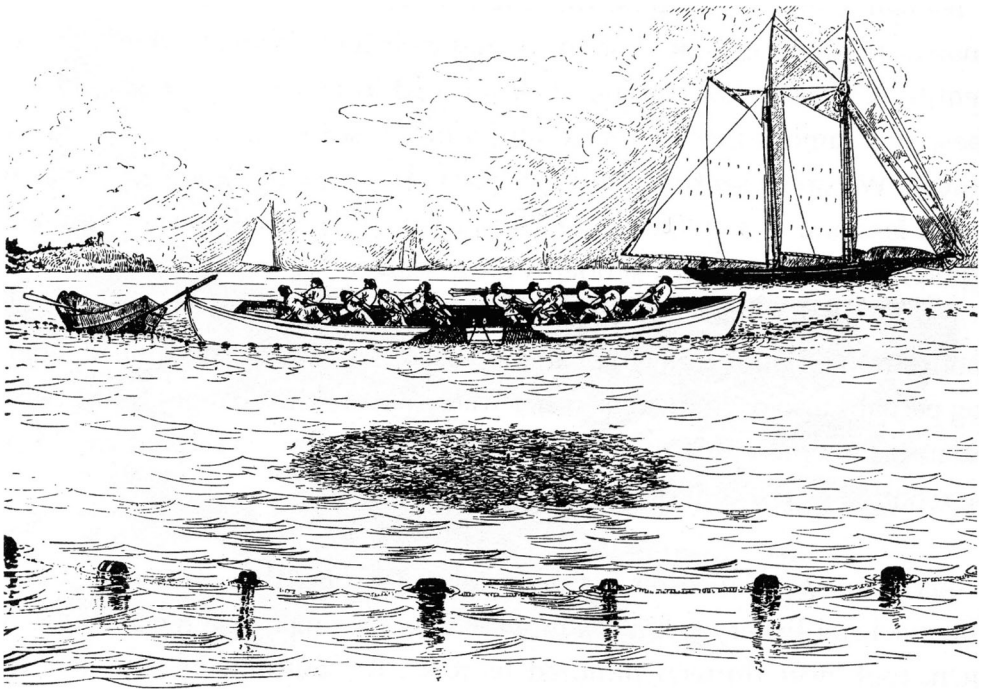

Fig. 6 Illustration of the nineteenth-century capture of a school of mackerel bunched together through use of a purse seine (Goode *et al.* 1884). It is not difficult to imagine how a distant view of the floats of such a net that had become non-lethally entangled on a swimming animal might be construed as being an enormous, undulating sea serpent if it was dragged along, bobbing up and down, over the surface of the water. There are many early accounts of marine animals becoming entangled in deployed fishing nets which were either recognized to be known species, or if not, were consequently regarded as being sea serpents (for example, see the epigraph in France 2016a)

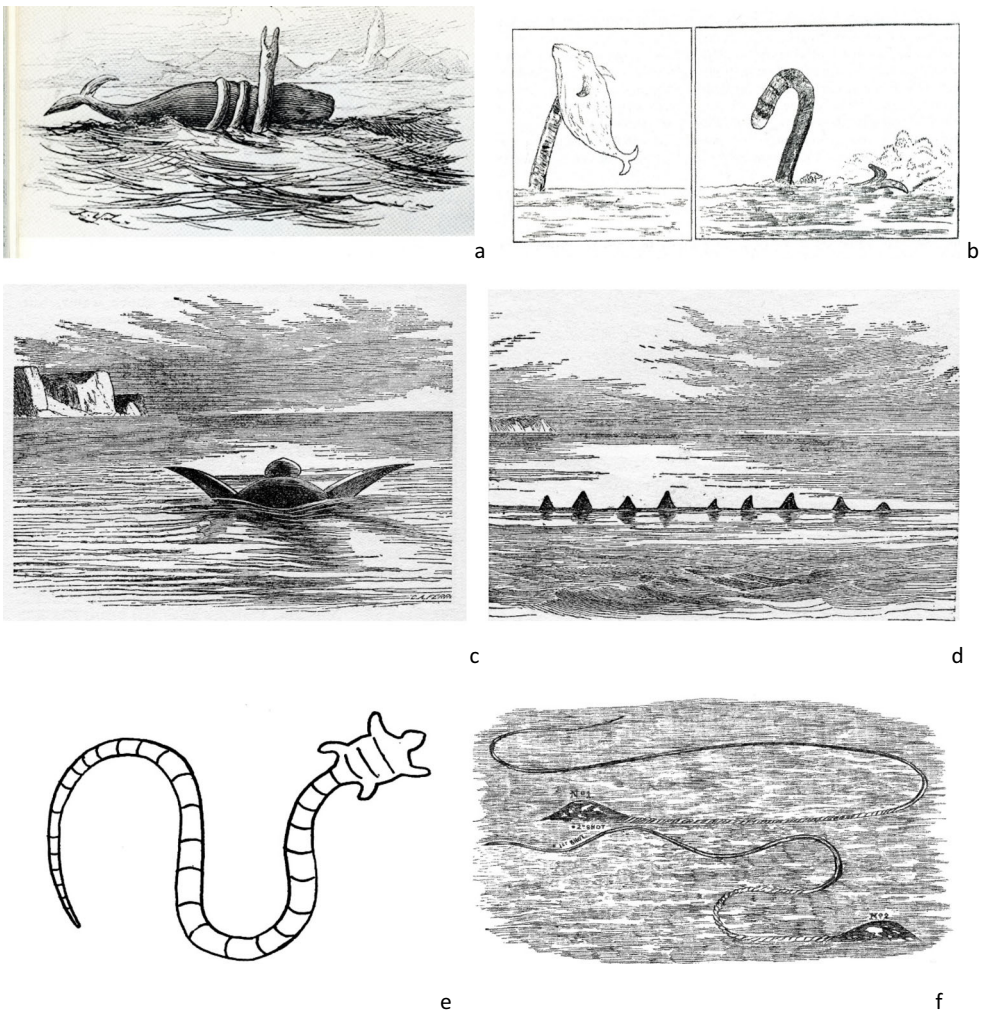

Fig. 7 **a** The most famous account of a cetacean observed to have been locked in mortal combat with a purported sea serpent, or simply a long string of entangling gear or debris wrapped around an unfortunate and struggling sperm whale? (1875 Brazil sighting – France 2016a); **b** Depictions of a purported sea serpent attacking a whale that resembles (left panel) a normal breaching whale with a thick line of debris entangled over its right fin, and the same whale moments later heaving the entangled gear or debris upward into the air while raising its tail to plunge back into the water (right panel) (1879 Japan sighting – France 2016a). **c** Frontend view of the *Osborne* UMO swimming away; and **d**) Long row of trailing serrated 'fins' of the same creature, suggesting an entangled sea turtle (1877 Sicily sighting – France 2017). **e** An UMO described as a "turtle-bodied snake" (1925 China Sighting – France 2016b). **f** A purported sea serpent, or simply an unidentified, surface-swimming and presumed air-breathing marine mammal entangled and trailing a long rope of maritime debris? (1857 South Africa sighting – France 2018)

(Fig. 8) as detailed below in the sightings from multiple sources collated by O'Neill (1999). The *Wiscasset Yankee* described an UMO sighted in 1831 in Boothbay Harbor, Maine, of an estimated length of 200 ft. with a general form "resembling that of an eel," and which moved by undulations "like a leech or bloodsucker … Although of such immense length, he made several very short quick turns, from which it may be inferred his body cannot be very large in circumference. His head and tail in one of these turns appeared within less than 20 feet of each other. Neither dorsal nor lateral fins could be discovered by anyone." In 1832, the *Lynn Weekly Messenger* reported an UMO sighting by more than 100 people in Boston Harbor off Nahant, the same area visited by the famous UMO of 1819. The creature sported a barrel-sized head, and "many bunches on his back were seen, supposed about forty in number." The *Boston Post* reported "a shoal of Sea Serpents" from 80 to 130 ft. length seen by dozens of people off Nahant the next year. The UMOs were observed "lying full length upon the water" and "showing twenty or thirty bunches or snake-like undulations at a time." In 1835, an UMO was observed by a ship's crew off Cape Cod that was described as having "something that looked like a mane upon

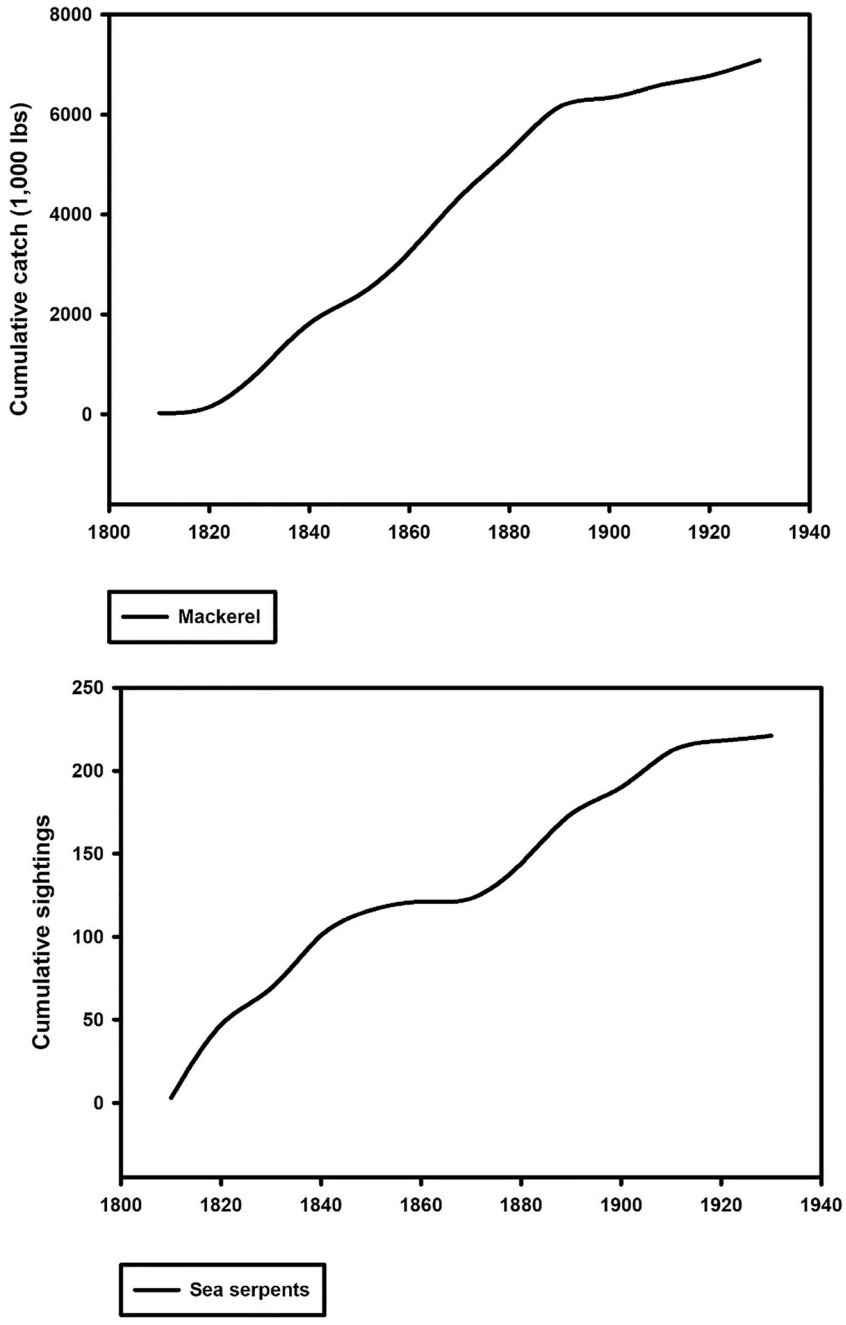

Fig. 8 Continued expansion of the fishery on mackerel in the United States and parallel trend in sightings of purported sea serpents in New England between 1804 and 1929. Upper panel – decadal cumulative catch of mackerel. Data derived from tables in Hoy and Clark (1967). Lower panel – decadal cumulative sightings of sea serpents. Data from O'Neill (1999). Note the mackerel fishery underwent a steady increase throughout most of the nineteenth century until it collapsed in the 1880s (Bolster 2012), as shown by the flattening of the line thereafter. Sea serpents continued to be sighted throughout the century, experiencing a decreased incidence during the periods of the Civil and Great Wars in the 1860s and 1910s, respectively, as shown by the flattening of the line during those periods

the top of it['s head and neck]." Later that year another boat, on passage from Boston to Kennebunk, Maine, saw an UMO with "several protuberances…along its head." Four years later, the *Kennebec Gazette* noted a group of fishermen in their boats, "credible men, not over credulous," who sighted a 100 ft. UMO in Wells Bay, Maine, that resembled "a long row of hogsheads or barrels with perhaps a foot or eighteen inches space between them." A month later, a group of fishermen in Kennebunk Harbor, Maine saw what might have been the same 100 ft. creature: "He had bunches or humps on his back about the size of a common barrel, with flippers at each end of them; was covered with scales the size of a common plate…and his motions resembled those of a snake." The creature was also observed in Boston Harbor, leading to an illustration (Fig. 9a) by an eyewitness that appeared in the *Mercantile Journal*.

In 1875, the *Boston Advertiser* noted that an individual in a boat chased a purported sea serpent around Nahant for 2 hours, repeatedly shooting at it at least 20 times, "but without apparent effect, though one ball seemed to strike it." In 1877, an UMO was seen near Gloucester Harbor: a "shapeless creature of enormous bulk" that caused great disturbance in the water, and which could suddenly disappear "down perpendicularly." The UMO was covered with what was thought to be "kelp" and had rough skin "like a gigantic alligator." The skin "was not only very rough, but the surface was very uneven, and covered with enormous humps of varying sizes, some being as large as a two-bushel basket. Near one end was a

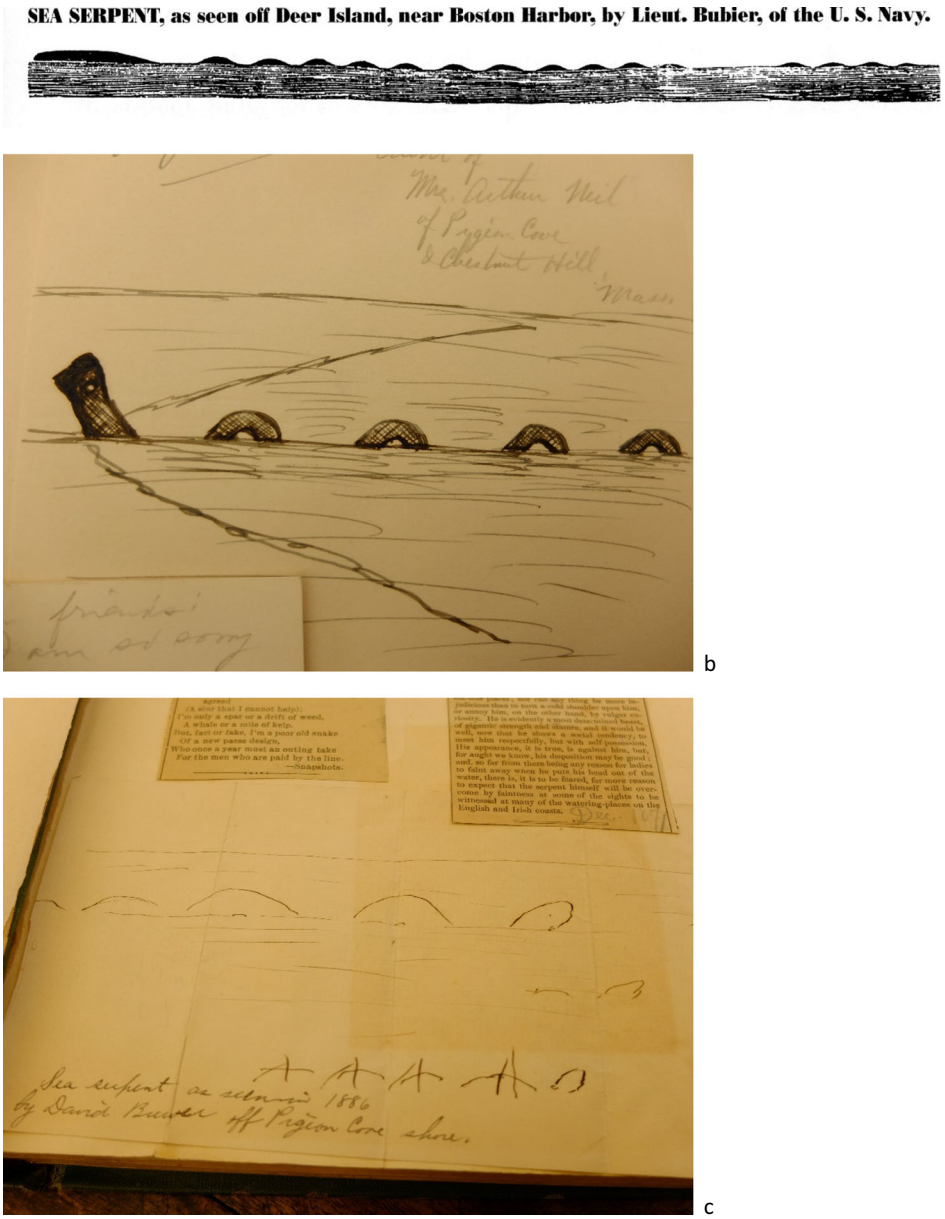

Fig. 9 Illustrations of nineteenth-century New England UMOs that, according to Heuvelmans (1968), the father of cryptozoology, are classic examples of the "many-humped" or "string-of-buoys" category of sea serpents, but which I posit the same with regard to being examples of entangled marine animals. **a** A 15-humped UMO sighted in Boston Harbor in 1839. **b** and **c** Two drawings from the scrapbook of Gloucester resident George W. Woodbury (photographed by author from Cape Ann Museum historical archives), each showing 4 of the 10 to 15 humps noted for an UMO repeatedly sighted off Cape Ann in 1886

marked depression, which we took to be the neck. In front of this the head (?) rose out of the water perhaps half as high as the body, but we saw no eyes, mouth fins, or the slightest indications of a tail." The *New York Herald* reported another observer who described the UMO, by this time affectionately referred to as "his snake-ship," as "about forty feet and…[having] twenty fins, or something like them, projecting out of the water about three inches, one foot apart, from the head to where the tail was supposed to be." In 1886, numerous sources reported Cape Ann once more played host to a mysterious UMO of more than 100 ft. that moved by vertical undulations but displayed no fins or flippers and had a back composed of "ten to fifteen ridges" (Fig. 9b and c). Another eyewitness account that surfaced decades later also described the UMO's movement being vertical, with its back displaying a "number of ridges in his movement and the distance between them which could be seen at the same time." Again, in 1896, a many-humped UMO was seen off Nahant spread out motionless "on the surface of the water across our bow" for a period of several minutes, its form could be clearly discerned, each hump being crowned by what appeared to be "a thick fleshy fin…along its back about three or four feet apart." A 1898 letter in the scrapbook of Gloucester resident and sea serpent aficionado George Woodbury, now at the Cape Ann Museum, describes an UMO seen in Maine that eyewitnesses first thought to be "a spar buoy with its base held stationary, spanking its length on the surface of the water with a circular motion, at varying lengths of from two to five seconds." Upon closer inspection "the monster straightened itself out to a form resembling a seventy-five-foot string of hogsheads [i.e., barrels]. Whether the body was creased in sections or the color marking camouflaged it as such, I am not sure."

In 1904, an UMO was once again seen in Boston Harbor, this time "about 70 feet long with about 40 humps or curves about the size of a man's body along its back and head, which it occasionally raised above the surface of the water, as large as a nail keg," and which moved by sinuous undulations. The next year a Massachusetts fisherman was actually knocked from his dory "by a seventy-foot sea serpent that was apparently attempting to disentangle itself from the lines of a lobster trap." Two years later, an UMO in northern Maine was repeatedly observed, "playing around a buoy" (*St. Croix Courier*). And in an 1912 article in the *Gloucester Daily Times,* the following encounter was documented by an individual acknowledged to be the region's most effective mackerel fisherman: "A small school of mackerel in the seine boat were pulling in the seine when a commotion was noticed among the fish, and the sea serpent, which had evidently been under the seine, made its appearance alongside the boat to the alarm and disgust of the crew, who had never seen anything like it before…[I]t became entangled in the seine, tearing it to pieces, and then started off at a 2.40 gait with the boat, seine and everything in tow, all the mackerel estimated at about 40 barrels, getting away." O'Neill (1999) suggests that: "perhaps the creature is unable to see the net and becomes entangled as it swims up on a closely packed meal." Finally, a *Boston Herald* article describes a 1925 Massachusetts sighting of a 125 ft. UMO that sported an array of "green scales about the size of tea trays" along its back.

In toto, we have a group of animals, observed over a period of a century, which can be described as having no noticeable facial or bi-lobate tail attributes, and which have highly flexible bodies of lengths equaling those of the largest whales but of only narrow circumference. Furthermore, the bodies are composed of a series of many segmented ridges or protuberances that resemble a string of barrels or kegs, which are unaffected by gunshot, and which move by vertical undulations when not floating motionless on the surface of the water. Displaying a propensity for becoming entangled in fishing nets, these UMOs sometimes exhibit what is thought to be a mane (perhaps netting?) as well as green-scales (possibly glass floats?).

Paxton (2009) demonstrated that when anecdotes of anomalous phenomena, such as those pertaining to UMOs, are considered in aggregate, they can constitute data meritorious of legitimate scientific study (see Table 4). I argue that the observed physical and behavioral characteristics from the post-Tambora sightings described above for New England (which, it is important to note, represent about 10% of the regional total over this century-long period) extend and are in concordance also to those of UMO sightings from around the world, which I believe to have been entangled whales and sea turtles based on how closely their characteristics match those for the obviously entangled animal observed in and around Gloucester in the years immediately following the volcanic eruption.

Entanglement in marine debris and both active and abandoned (i.e., 'ghost') fishing gear is a serious environmental problem affecting the abundance and biodiversity of more than 200 species of marine animals (NOAA 2014). In at least a half-dozen additional, but not as thoroughly documented, post-Tambora sightings of UMOs in New England, eyewitnesses described a large object that could be construed as a whale. A further three such sightings specifically mentioned the proximity of a whale, in one case it being locked in combat with the presumed sea serpent, whereas in another case, the UMO was described as appearing "to be a cross between an eel and a whale." Two other sightings specifically mentioned the presence of small cetaceans in close association with the presumed sea serpent, in one case stating the monster to have been in active pursuit of a porpoise. Four sightings referred to large fish being associated with the sea serpent, in one case the UMO being in pursuit of a swordfish, in another it being attacked by a swordfish, and in a third, the sea serpent resembling a shark while it dragged a boat of fishermen through the water. And finally, one sighting mentioned the head at the front end of a

Table 4 Observed physical and behavioral attributes of UMOs posited to have been entangled animals. Numbers shown indicate the incidence of occurrence for 20 different sightings in New England between 1831 and 1925 (this study), 28 different sightings of putatively entangled whales (France 2016a, 2018), and 16 different sightings of putatively entangled sea turtles (France 2016b, 2017)

Attribute	New England	Cetaceans	Chelonians
Notable length	9	12	7
Body composed of a series of irregular, jointed component parts (multiple humps, coils, or a ridge)	9	6	8
Rapid speed of movement	3	6	–
Notable flexibility of body	1	4	4
Vertical undulating movement of body segments	3	3	4
Body components likened to kegs or barrels, and sometimes scales or saucers	2	3	4
Oblivious of surroundings or impervious to disturbance	2	2	3
Overall body likened to a string of kegs or buoys	3	2	0
Obvious trailing wake or water disturbance	2	2	3
Floating motionless, gently swaying in waves, or moving very slowly	2	2	5
Narrow, tapering, sinuous, snake/eel-like shape, often with absence of a caudal fin or lateral appendages	3	14	10
Extended body pulled down into water, thrown up into the air, or thrashed about on the surface	1	11	1
Presence of a horn, spike, spine, mane, or other protuberance (sometimes identified as a head)	2	5	6

long sea serpent to resemble that of a seal. It is not a reach to imagine how sightings of recognized animals pulling a train of entangled material might give the impression of them being pursued by long serpentine monsters.

Alexander *et al.* (2017) make the point that the shift from riverine to marine fisheries in New England in the 1810s would have happened anyway, as occurred in late medieval and Renaissance Europe (Hoffman 2005; Lajus *et al.* 2013). The difference is that the adaptive response in the 1810s, necessary due to the Tambora climate disaster, was accomplished within half a decade, and that in terms of resilience, the rate of change may be just as, or even more, important than the magnitude of that change. The Gloucester UMO and all "his Snake-ship's" descendants emerged from the "most catastrophic sustained weather crisis of the millennium" (Wood 2014) and would have a profound influence on nineteenth-century scholarly discussions about America's role in evolutionary and geological science in general, and natural history in particular (Brown 1990; Lyons 2009; Regal 2012; France 2019).

Finally, with reference to Europe's preceding historical shift from riverine to marine fishing with the corresponding deployment of extensive fishing gear, it is interesting to speculate whether there was any relationship, other than coincidence, between the extreme weather of the Little Ice Age (due to notable volcanic eruptions, reduced solar radiation from more sunspots, and massive reforestation from the catastrophic die-off of indigenous peoples of North America) producing consequent social-ecological upheavals (Blom 2019), and the plethora of cartographic depictions (van Duzer 2013) and early textural descriptions (Oudemans 1892) of sea monsters during this period, some of the latter being remarkably similar to those of the Gloucester UMO vis-à-vis entanglement. After the Medieval Warm Period, anadromous salmon moved northward, cod southward, and offshore stocks of herring around the British Isles increased (Barrett *et al.* 2004; Hoffman 2005). Collapses in freshwater fisheries due habitat disturbance and overfishing, and in marine fisheries due to regional cooling, led to shifts from artisanal to intensive exploitation in attempt to provide fish for religious dietary requirements. It is possible that the expanded deployment of fishing nets during this period in northern Europe (Ojaveer and MacKenzie 2007) also served to create sea serpents in a parallel fashion through entanglement as occurred later on the other side of the Atlantic in New England.

Conclusions: History and Conservation

Historical interpretations need to become *de rigueur* in conservation biology, lest the practice and its interpretations and proscriptions be considered incomplete (Crumley 1994; Meine 1999). In particular, past societal attitudes and actions are very much ecological driving forces paramount to shaping current and future ecosystems (Cronon and McDonnell 1993; Szabo and Hedl 2011). Massive alterations, for example, have occurred in the abundance and diversity of marine fauna in consequence of millennia of exploitative harvest and hunting (Starkey *et al.* 2008). As Alexander *et al.* (2017) state, "historical ecology is a forensic pursuit." My conclusion from the narrative evidence is that populations of marine animals in the Anthropocene have been subjected to pressure not only from direct fishery exploitation (e.g., Lotze *et al.* 2006) but also

possibly from being by-catch due to entanglement in deployed fishing gear for a much longer period than is commonly presumed. In this respect, it is the present illation that past events of extreme and rapid climate (global) and weather (regional) change can indeed promulgate far-reaching, and sometimes surprising, ripple effects in complex social-ecological systems, the implications of which can be long lasting.

Compliance with Ethical Standards

Conflict of Interest The author declares that there are no conflicts of interest.

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